Decision Analysis Tools and Retail Food Policy

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Abstract

Retail food policy deliberations play an important role in the development and evaluation of recommendations that shape national retail food policy. Standard models, principles, tools, and techniques can serve as useful resources for advancing uniformity and consistency in the deliberation and decision-making process. The purpose of this study is to apply quantitative decision analysis tools for comparing the impact of competing retail food safety policies. We will show how Multi-Criteria Decision Analysis (MCDA) and Stochastic Multicriteria Acceptability Analysis (SMAA) can give the analyst easy to understand quantitative data to help inform a final determination about the efficacy and feasibility of food safety policy recommendations. Specifically, we will show how MCDA can provide weighted sums of partial utilities for each food safety policy alternative being considered and how SMAA can estimate the probability of rank order for each alternative. Because these tools incorporate stakeholder and expert opinion, they allow the analyst to make use of the information and expertise available to them, which can be particularly useful in prospective policy analyses where information and data may be scarce or incomplete.

Introduction

Retail food policy deliberations play an important role in the development and evaluation of recommendations that shape national retail food policy. One notable example is the Conference for Food Protection deliberations for changes to the Retail Food Code. The FDA Food Code is a guidance for mitigating risk factors that are known to cause or contribute to foodborne illness outbreaks associated with retail and foodservice establishments. The Retail Food Protection Staff (RFPS) in FDA's Center for Food Safety and Applied Nutrition (CFSAN) is responsible for the development and revision of the Food Code. Every two years, scientists and policy makers from all levels of government, industry, academia, as well as consumers, attend the Conference for Food Protection (CFP) to propose and deliberate on recommended changes to the Food Code. Recommendations that are viewed favorably are forwarded to the FDA for consideration.

Standard models, principles, tools, and techniques can serve as useful resources for advancing uniformity and consistency in the deliberation and decision-making process but can be limited in their usefulness when certain decision challenges are present. Examples of such challenges are when it is difficult to define benefits and risks because data are scarce, and when there are multiple relevant criteria, such as public health outcomes, feasibility, and budgetary impact that need to be considered. Decision Analysis tools are methods that can address such challenges and can be adapted to the complexity of the problem and the time available for decision-making. From qualitative methods that help the decision maker frame and document the problem, to quantitative methods involving ranking, weights, and simulation, Decision Analysis incorporates stakeholder and expert opinion, which allows the analyst to make better use of the information and expertise that is available to them, which may be incomplete or uncertain

The purpose of this study is to demonstrate how Decision Analysis tools, such as Multi-Criteria Decision Analysis (MCDA) and Stochastic Multicriteria Acceptability Analysis (SMAA), can give the analyst easy to understand quantitative data to help inform a final determination about the efficacy and feasibility of food safety policy recommendations. Specifically, we will show how MCDA can provide weighted sums of partial utilities for each food safety policy alternative being considered, and how SMAA can estimate the probability of rank order for each food safety policy alternative.

Ref:
1. *Decision Analysis Society, "Informs," [Online]. Available: https://connect.informs.org/das/home. [Accessed 4 11 2020].*
2. *University of Baltimore, "Tools for Decision Analysis: Analysis of Risky Decisions," [Online]. Available: http://home.ubalt.edu/ntsbarsh/opre640a/partix.htm. [Accessed 4 11 2020].*
3. *J. Ulvila and R. V. Brown, "Decision Analysis Comes of Age," Harvard Business Review, vol. 60, no. 5, pp. 130-141, 1982.*
4. *Marasteanu, I. Julia, et al. "Advancing retail food policy debates: Estimating the risk of contaminated servings of food attributed to employee food handling practices in retail food establishments." Journal of food protection 81.12 (2018): 2034-2039.*

Materials and Methods

Multi-Criteria Decision Analysis (MCDA)

- We have a set of m alternatives $\{x_1, x_2, x_3, \dots x_m\}$ that are evaluated in terms of *n* criteria (**Fig. 1, Table 1**)
- We assume that the decision makers (DM) have a consensus on some decision model M(**x,w**) that is suitable for the problem setting
  - **x** = $[x_{ij}]$ is a matrix of criteria measurements with i referring to the alternative and j to the criterion (**Table 1**)
  - **w** = $[w_j]$ is a vector of preference parameters representing the DMs' subjective preferences (**Fig. 3, Table 3**)
- A linear utility function defines the overall utility of an alternative as a weighted sum of *partial utilities*:
  - $u(\mathbf{x}_i, \mathbf{w}) = w_1 u_{i1} + w_2 u_{i2} + \dots + w_n u_{in}$ (**Fig. 2, Table 2, Fig. 3, Table 4**)
  - The partial utilities u_{ij} are computed from the actual criteria measurements x_{ij} through linear scaling so that the worst value is mapped to 0 and the best value becomes 1
  - Typically, the weights should be non-negative and normalized so that their sum is 1 (**Table 3**)
  - The alternative with the highest partial utility value is the "best" alternative

Stochastic Multicriteria Acceptability Analysis (SMAA)

- SMAA is a stochastic MCDA problem, where incomplete criteria and preference information are represented by suitable (joint) probability distributions $f_X(\mathbf{x})$ and $f_W(\mathbf{w})$ (**Fig. 4, Table 5**)
- We now look at the *acceptability index* a_i. The acceptability index of each efficient alternative measures the variety of criteria and/or weights that make alternative $\mathbf{x}_i$ the most preferred (**Fig. 5**)

Ref: Lahdelma, R., & Salminen, P. (2010). Stochastic multicriteria acceptability analysis (SMAA). In Trends in multiple criteria decision analysis (pp. 285-315). Springer, Boston, MA.

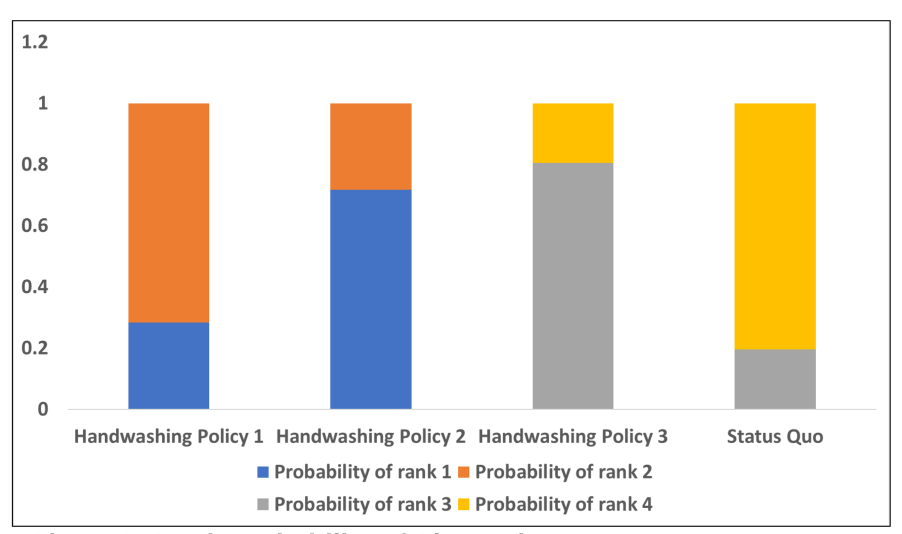

Figure 5. Rank Probability of Alternatives

Running Monte Carlo simulation to get probabilities that each alternative ranks first, second, third, or fourth

Table 5: Assignment of Ranges

Alternative/ Criteria	Public Health Impact		Feasibility		Economic Impact		Budgetary Impact		Compliance		Regulatory Acceptability		Industry Acceptability		Equity	
	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound
Handwashing Policy 1	40	60	60	75	65	75	45	55	65	80	45	55	45	55	15	35
Handwashing Policy 2	75	85	10	30	60	70	65	80	65	75	40	60	40	60	65	80
Handwashing Policy 3	65	75	15	30	45	55	40	55	15	30	60	75	60	75	45	60
Status Quo	20	30	45	55	20	35	20	40	60	70	75	85	75	85	20	40

Results and Discussion

Note: The values and other information in the examples are fictional and meant to convey one approach to implementing the step being described. The examples do not reflect the only way to approach the steps.

Identify and describe the food retail policy issue which you are interested in evaluating.
Example: We are interested in evaluating policy options pertaining to employee handwashing in restaurants.

Identify the criteria that are most important in evaluating the food retail policy issue identified in the previous step.
Example: The criteria determined to be most important when evaluating our identified food retail policy issue are public health impact, feasibility, economic impact, budgetary impact, expected compliance, regulatory acceptability, industry acceptability, and equity.

Identify the primary and alternative policy options
Example: The policy alternatives that we can choose from to address our identified issue are Handwashing Policy 1, Handwashing Policy 2, Handwashing Policy 3, and the Status Quo (no change)

For each policy option, rate each criterion as low/less favorable, medium/favorable, or high/more favorable.
Example: We draw from our expertise to make judgement calls on the ratings.

Ref:
1. *How to use multiattribute utility measurement for social decisionmaking." IEEE transactions on systems, man, and cybernetics 7.5 (1977): 326-340.*
2. *Centers for Disease Control and Prevention. CDC's Policy Analytical Framework. Atlanta, GA: Centers for Disease Control and Prevention, US Department of Health and Human Services; 2013.*

Figure 1. Defining the Problem: Pre-steps or Inputs

Turn the categorical values into numerical values by having low/less favorable = 0, medium/favorable = 0.5, and high/more favorable = 1.

For each alternative, sum these values over all the criteria (this sum represents the utility of the alternative).

The final product is a ranking of the policy options based on these sums.

Ref: How to use multiattribute utility measurement for social decisionmaking." IEEE transactions on systems, man, and cybernetics 7.5 (1977): 326-340.

Figure 2. Perform Multi-Criteria Decision Analysis

Weights are used if the criteria identified are deemed to not be equally important (e.g., one criterion may carry more weight than another).

Rank the criteria defined above in order of importance
Example: From most to least important, we have public health impact, feasibility, expected compliance, economic impact, budgetary impact, industry and regulatory acceptability, and equity

Assign the criteria an importance rating.
To do this, give the least important criterion a value (weight) of 10. Then assign the remaining criteria weights based on their importance relative to the least important criterion.

Normalize the weights such that they add up to 1 (this is done by taking each weight and dividing it by the sum of all the weights).

Multiply the criteria values by the normalized weights and sum for each alternative.

The final product is a ranking of the policy options based on these weighted sums.

Ref: How to use multiattribute utility measurement for social decisionmaking." IEEE transactions on systems, man, and cybernetics 7.5 (1977): 326-340.

Figure 3. MCDA with Weights

SMAA is to be used if more granularity is needed to capture the differences in criteria between alternatives (e.g., if two or more policies are so similar in terms of criteria that using the low, medium, and high categorization does not capture their differences)

For each policy option, assign each criterion a range of values within 1 to 100, where 1 is the lowest/least favorable outcome for the criterion, and 100 is the highest/most favorable outcome for the criterion.

Run a Monte Carlo Simulation.
The Monte Carlo simulation draws criteria values from a uniform distribution based on the minimum and maximum values for the criteria values. For each draw, the simulation calculates the normalized weights and the weighted or non-weighted sums. It repeats this many times (hundreds of thousands of draws/iterations), each iteration providing different weighted or non-weighted sums, and therefore different rankings of alternatives. In essence, this just runs the MCDA analysis over and over for many possible criteria values. The number of times over the hundreds of thousands of iterations that each alternative ranks first, second, etc. is then counted and used determine each alternative's probability of being the best, second best, etc.

Ref: Lahdelma, R., & Salminen, P. (2010). Stochastic multicriteria acceptability analysis (SMAA). In Trends in multiple criteria decision analysis (pp. 285-315). Springer, Boston, MA.

Figure 4. Perform Stochastic Multicriteria Acceptability Analysis (SMAA)

Table 1: Inputs

Alternative/ Criteria	Public Health Impact	Feasibility	Economic Impact	Budgetary Impact	Compliance	Regulatory Acceptability	Industry Acceptability	Equity
Handwashing Policy 1	medium/ favorable	high/more favorable	high/more favorable	medium/ favorable	high/more favorable	medium/ favorable	low/less favorable	low/less favorable
Handwashing Policy 2	high/more favorable	low/less favorable	high/more favorable	high/more favorable	high/more favorable	medium/ favorable	high/more favorable	high/more favorable
Handwashing Policy 3	high/more favorable	low/less favorable	medium/ favorable	medium/ favorable	low/less favorable	high/more favorable	medium/ favorable	medium/ favorable
Status Quo	low/less favorable	medium/ favorable	low/less favorable	low/less favorable	high/more favorable	high/more favorable	low/less favorable	low/less favorable

Turning categorical values into numerical values, calculating sum of utilities

Table 2: MCDA

Alternative/ Criteria	Public Health Impact	Feasibility	Economic Impact	Budgetary Impact	Compliance	Regulatory Acceptability	Industry Acceptability	Equity	Sum of utilities	Rank
Handwashing Policy 1	0.5	1	1	0.5	1	0.5	0	0	4.5	**2**
Handwashing Policy 2	1	0	1	1	1	0.5	1	1	6.5	**1**
Handwashing Policy 3	1	0	0.5	0.5	0	1	0.5	0.5	4	**3**
Status Quo	0	0.5	0	0	1	1	0	0	2.5	**4**

Adding additional granularity and uncertainty to the criteria ratings

Table 3: Assignment of Weights

Criteria	Public Health Impact	Feasibility	Economic Impact	Budgetary Impact	Compliance	Regulatory Acceptability	Industry Acceptability	Equity
Rank	1	2	4	5	3	6	6	7
Weight (assign a 10 to the lowest rank/highest value)	40	35	25	20	30	15	15	10
Scaled weight	0.21	0.18	0.13	0.11	0.16	0.08	0.08	0.05

Calculating weighted sums

Table 4: MCDA with weights

Alternative/ Criteria	Weighted sum of partial utility	Rank
Handwashing Policy 1	0.67	**2**
Handwashing Policy 2	0.78	**1**
Handwashing Policy 3	0.47	**3**
Status Quo	0.33	**4**

Adding additional granularity and uncertainty to the criteria ratings

Conclusion

Decision Analysis tools can be used to tackle decision challenges facing Retail Food policy makers as they allow for the decision maker to compare multiple criteria at once, weight criteria based on importance, and account for uncertainty in criteria values and weight values. Decision Analysis tools are flexible and can be changed based on the decision problem at hand (e.g., one decision problem may include 5 criteria, another may include 50; one decision problem may heavily weigh cost savings, another may not weigh cost savings very heavily).

The results generated by Decision Analysis tools are not intended to provide a "final" answer to what alternative is best. Rather, the rankings show which alternative has (the highest probability of having) the highest utility based on the assumptions and estimates made by experts. If other pertinent information exists, it must be considered in conjunction with the rankings. The highest (probability of) ranking first may not necessarily point to the "best" alternative but rather the most favorable. These estimates give the decision maker easy to understand quantitative data that can be used with other information to help make a final decision.